Stability and Electrical Properties of High Temperature p-n Junction of NiO-ZnO System

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Introduction

High temperature p-n junction has been received much attention in intermetalic and oxide systems. But at high temperature, the performance degrades due to interdiffusion at the junction. The junction which is thermodynamically equilibrated p-type and n-type materials provides us the long life p-n junction at high temperature. It's well known that NiO is p-type semiconductor and ZnO is n-type. Despite many reports and data on NiO-ZnO system, there is little information of phase diagram. The purpose of this study is to clear the phase diagram of this system and properties of high temperature p-n junction of NiO-ZnO System.

Experimental

Quantitative analysis and microstructure

Based on the reported tentative phase relations [1-2], NiO with 40 mol% ZnO (z40) and NiO with 90 mol% ZnO (z90) were chosen as samples in the two-phase region. Powders of NiO (99.97%, High Purity Chemicals) and ZnO (99.99%, High Purity Chemicals) were thoroughly mixed in appropriate ratio. The powder mixtures were pressed at 120MPa and sintered at 1673 K for 43.2 ks (12h) in air. Resulting samples were annealed at 873~1273 K for 259.2 ks (72h) in air and cooled down to room temperature within 0.18 ks (3min). The samples were identified by X-ray diffraction (XRD) and microstructures of samples were analyzed with scanning electron microscope (SEM) and electron probe x-ray micro analyzer (EPMA). Distribution of saturated NiO solid solution (NiO_{SS}) and ZnO solid solution (ZnO_{SS}) was confirmed by SEM. The solubility limits were evaluated by analyzing the large grains of the major phase with EPMA. Atomic ratios were decided by using ZAF method.

Electrical properties of junction

Thermoelectric power was measured on sintered NiO_{SS} and ZnO_{SS}, and confirmed that NiO_{SS} is p-type and ZnO_{SS} is n-type. The two compounds were connected to make a p-n junction and *I-V* characteristics were measured in air at 673~973 K. Stability of the junction was evaluated by long time measurement as shown in figure 1. Starting from 673 K, temperature was fixed until electrical property was constant. After that, temperature was changed to next step. Finally, temperature was returned to 673 K, the properties of the junction were compared between stage 1 and stage 5.

Results & Discussion

Figure 2 shows the phase diagram of NiO-ZnO system obtained in this work. Below 1200 K, solubility limits of both side scarcely depend on temperature, while above 1200 K, stability limits increase with increasing temperature. Figure 3 (a) shows *I-V* characteristics of stage 1 and stage 5 of z30 / z95 junction which consists of compounds in the two-phase area. In spite of change of high temperature as shown in figure 1, these *I-V* characteristics at 673 K are almost same. In order to compare equilibrated compounds and non-equilibrated compounds, *I-V* characteristic of z25 (was single phase) / z95 junction was measured. Non-ohmic characteristics degraded evidently while z30/z95 junction was stable for long time. These results indicate that the p-n junction which consists of equilibrated compounds was very stable at high temperature.

Conclusion

The solubility lines on phase diagram of NiO-ZnO system were cleared at 873~1273 K. the *I-V* characteristics of the p-n junction with NiO-ZnO system were non-ohmic, and this junction consist of equilibrated compounds is very stable at high temperature for long time. This study indicates a possibility of high temperature long life p-n junction with equilibrated compounds.

Reference

[1] C. H. Bates, W. B. White, R. Roy, *J. Inorg. Nucl. Chem.*, **28**, 397 (1966).
[2] Dong-Sook Sinn, *Solid State Ionics*, **83**, 333 (1996).

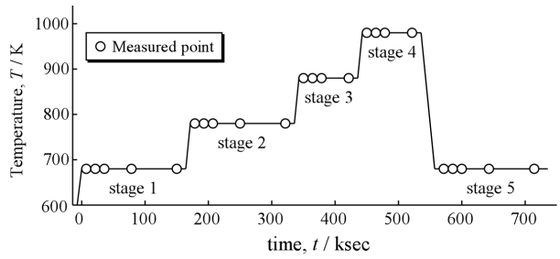

Figure 1. Temperature profile.

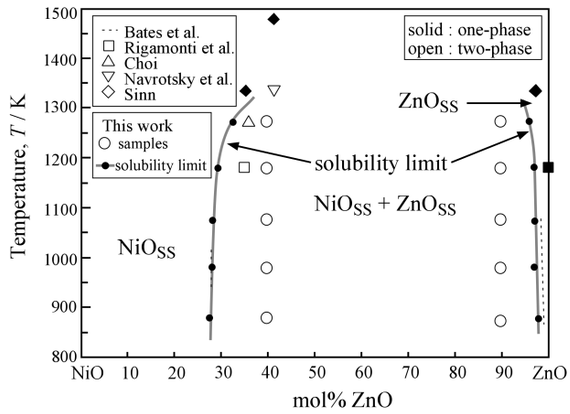

Figure 2. Phase diagram of NiO-ZnO system.

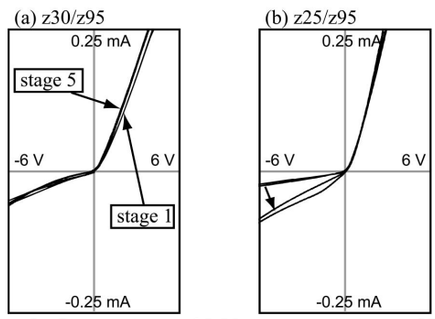

Figure 3. Comparison of I-V characteristics at 673 K, (a) stability of z30/z95,(b) stability of z25/z95.